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TITLE: PASSIVE SOLAR ECONOMICS IN 15 NORTHWEST L **MASTER**

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PASSIVE SOLAR ECONOMICS IN 15 NORTHWEST LOCATIONS

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ABSTRACT

The economic performance of Trombe wall and direct gain
passive solar heating designs are evaluated using the
LASL/UNM solar economic performance code. Both designs
are integrated into a ranch style tract home concept there-
by facilitating intra-regional comparison. The economic
performance of these systems is evaluated for 15 sites in
the Northwest region. Space heating loads have been locally
specified. System sizes have been optimized against the
natural gas and electric resistance heating alternatives,
the current price and future escalation of which is estab-
lished for each locale. Sensitivity analysis is conducted
to determine the maximum competitive add-on costs for each
system under a specified set of energy price, solar per-
formance and economic conditions.

INTRODUCTION

As the interest in passive solar energy heating grows, so
does the need for consistent economic and technical analysis
of alternative designs in order to evaluate their relative
cost competitiveness. This paper builds on and expands work
reported previously [1,2], focusing on the Northwest. Two
generic passive systems--Trombe wall and direct gain--are
assessed against the backdrop of locally specified home
heating loads and energy prices. Results are reported for
15 sites in Washington, Oregon and Idaho.

In the following section we review the methodology. This
includes design and performance assumptions, incremental
costs, energy futures, optimization and life cycle costing.
The third section contains descriptions of selected inputs,
including home heating loads, collector area calculations,
solar costs, fuel prices and economic assumptions. Maps
and tables are used to display some of the input data. Sec-
tion 4 contains an evaluation of total and variable costs
goals--the highest economically feasible system cost. The
last section compares the costs and benefits of the Trombe
wall system to those of the direct gain system. Both natural
gas and electric resistance comparisons are given for the
region.

METHODOLOGY

Six basic steps are employed in our regional evaluation of
solar economic performance. These are (a)the designation
of the residence design, (b)the specification of home heat-
ing loads, (c)the specification of annual thermal perfor-
mance of the passive designs, (d)calculation of solar add-
on costs, (e)specification of conventional energy prices
and futures by locale, (f)determination of economic com-
petitiveness of the designs. A more thorough discussion
of methodology can be found in [1,2].

The single family residence is of TEA design [3]: a one-
story slab on grade structure with 1536 ft^2 of living
space. Space heating loads are computed by locale based
on site specific building heat loss factors and annual

average heating degree days. The National Conference of
States on Building Codes and Standards (NCSBCS) model code
has been used for this purpose [9]. Map 1 shows the heat
loss factors used for the 15 locations.

MAP 1
SOLAR 79 NORTHWEST
CALCULATED HEATING LOADS
degree days x btu/sq ft/dd

MILLIONS OF BTU

< 80	80-89	90+
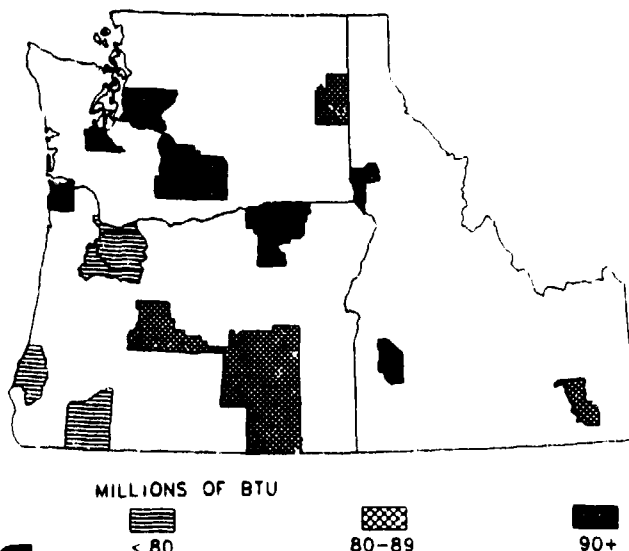
Results from modified solar-load ratio correlation pro-
cedures calculated by the LASL Q-11 Solar Energy Group [7]
are used to estimate solar performance [5] of each design.
A glazing area (ft^2) requirement for each desired level of
solar fraction by locale is derived by dividing the
LOAD/AREA (Btu/DD/ft^2) ratio from the simplified perfor-
mance tables into the previously calculated home heating
LOAD (Btu/DD for all surfaces other than glazing area).
Maps 2 and 3 show collector area requirements for the direct
gain with night insulation system (DGNI) and Trombe wall
with night insulation system (TWNI) respectively for 30%
solar contribution.

With the glazing area-solar contribution relationship estab-
lished we are able to optimally-size the passive designs
under a stated set of economic and alternative fuel con-
ditions. The optimization presented here is done assum-
ing an add-on cost of $16/ft^2 of glazing area [3]. All
other economic assumptions are shown in Table 1.

Fuel prices (base year 1978) were gathered for a large
number of cities [7,8]. Where information was missing
or inadequate for our purposes, a surrogate city was chose
and that city's fuel prices used. The base year prices ha

been escalated using National Energy Act (NEA) assumptions. Table 2 shows 1979 and 1990 fuel prices for natural gas and electric resistance.

MAP 2
SOLAR 79 NORTHWEST
COLLECTOR AREA REQUIREMENTS
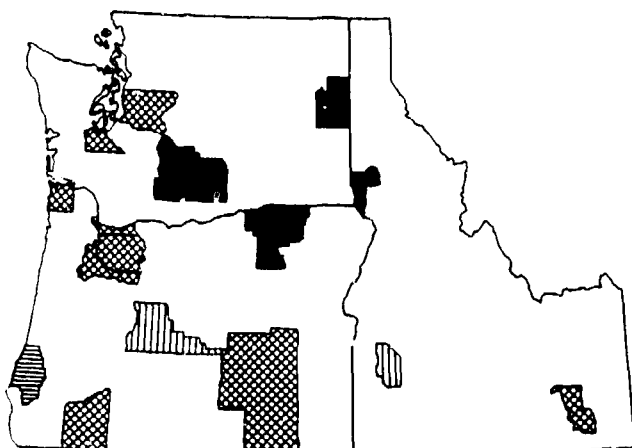DIRECT GAIN WITH NIGHT INSULATION
30 percent fraction
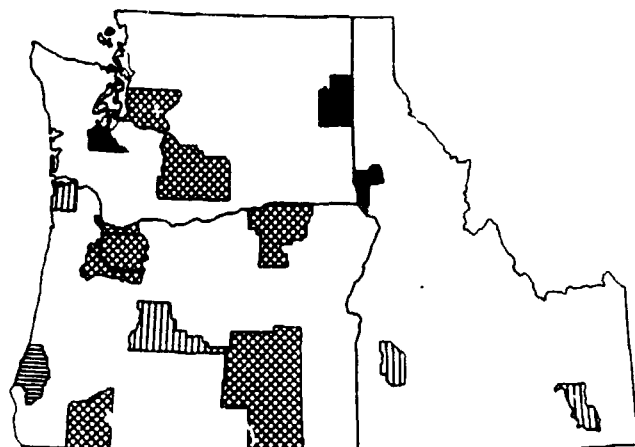
SQUARE FEET

▤	▥	▦	■
<200	200-225	226-249	250+

MAP 3
SOLAR 79 NORTHWEST
COLLECTOR AREA REQUIREMENTS
TROMBE WALL WITH NIGHT INSULATION
30 percent fraction

SQUARE FEET

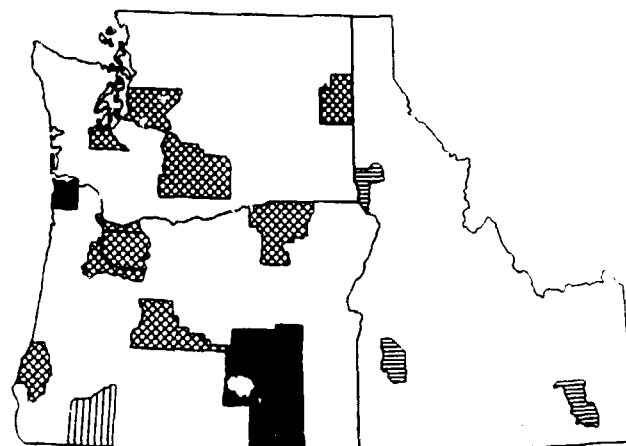| ▤	▥	▦	■
<200	200-225	226-249	250+

at 30% solar contribution for DGNI and TWNI systems.

MAP 4
SOLAR 79 NORTHWEST
MAXIMUM SOLAR COSTS
TROMBE WALL WITH NIGHT INSULATION
30 percent fraction
FUEL IS NATURAL GAS

DOLLARS
16/sq ft assumed

▤	▥	▦	■
<2500-3000	3001-3500	3501-4000	4001+

MAP 5
SOLAR 79 NORTHWEST
MAXIMUM SOLAR COSTS
TROMBE WALL WITH NIGHT INSULATION
30 percent fraction
FUEL IS ELECTRIC RESISTANCE
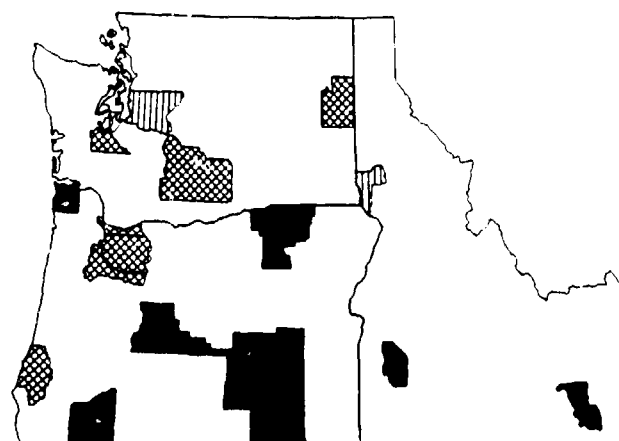
DOLLARS
16/sq ft assumed

▤	▥	▦	■
<2500-3000	3001-3500	3501-4000	4001·

COST GOALS

The cost goals approach attempts to identify the maximum cost (variable or total) at which the system is feasible. Put simply, if the annualized cost of the system is just equal to the annualized cost of the fuel being replaced by the solar contribution, the consumer breaks even. This breakeven cost is the maximum one could pay and still call the system feasible. Table 3 identifies this maximum variable cost for two system types (TWNI and DGNI), for two fuel alternatives (natural gas and electric resistance) at three levels of solar contribution (15%, 30% and 45%). Maps 4 through 7 show the maximum allowable total solar cost

COSTS AND BENEFITS OF ALTERNATIVE SYSTEMS

In the economic performance evaluation we employ a varian of life cycle cost analysis [1, 2, 6]. We evaluate a hom heating system that includes a solar component providing from 5 to 95 percent of the required heat. The net prese value (NPV) of the solar component (discounted present va of solar system benefits minus solar system costs) over t system life is maximized. This is exactly equivalent to minimizing the delivered cost of heat over the lifetime o the system. Simple payback is defined as the number of years it takes for the savings on fuel costs attributable to the sol system to equal the cost of the system. Tab

4 and 5 give results of a comparison between TWNI and DGNI systems for natural gas and electric resistance, respectively.

CONCLUSIONS

- The economic analysis is very sensitive to the cost of the alternative fuel. Our analysis can only benefit from up-dated fuel cost information.

- Trombe wall and direct gain passive solar designs (with a night insulation option) can compete economically today against electric resistance in most locations. They cannot compete where the price of electric resistance is less than 2.25 cents per kwh.

- TWNI and DGNI can compete against natural gas in most locations. They cannot compete where gas is very cheap.

- The direct gain system seems to perform somewhat better than the Trombe wall when NPV is used as a criteria.

- Feasibility of either system is more sensitive to solar add-on costs in the natural gas alternative than in the electric resistance alternative.

MAP 6
SOLAR 79 NORTHWEST
MAXIMUM SOLAR COSTS
DIRECT GAIN WITH NIGHT INSULATION
30 percent fraction
FUEL IS NATURAL GAS

DOLLARS
$16/sq ft assumed

|			
2500-3000	3001-3500	3501-4000	4001+

MAP 7
SOLAR 79 NORTHWEST
MAXIMUM SOLAR COSTS
DIRECT GAIN WITH NIGHT INSULATION
30 percent fraction
FUEL IS ELECTRIC RESISTANCE

DOLLARS
16/sq ft assumed

<2500-3000	3001-3500	3501-4000	4001+
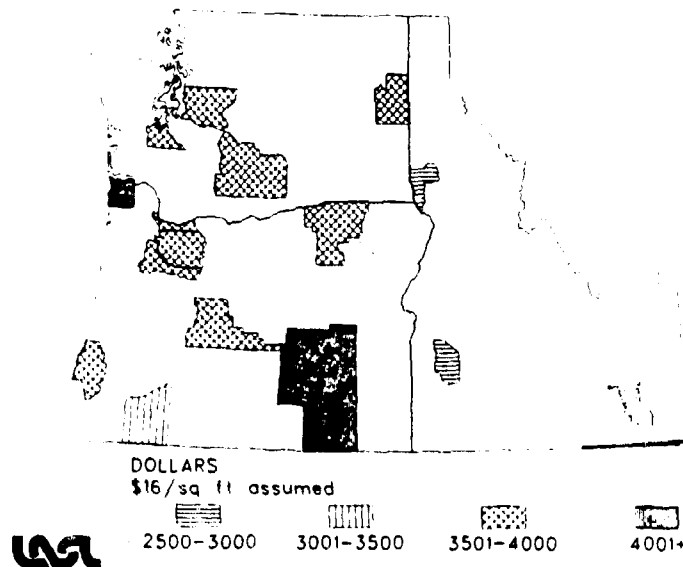
TABLE 1

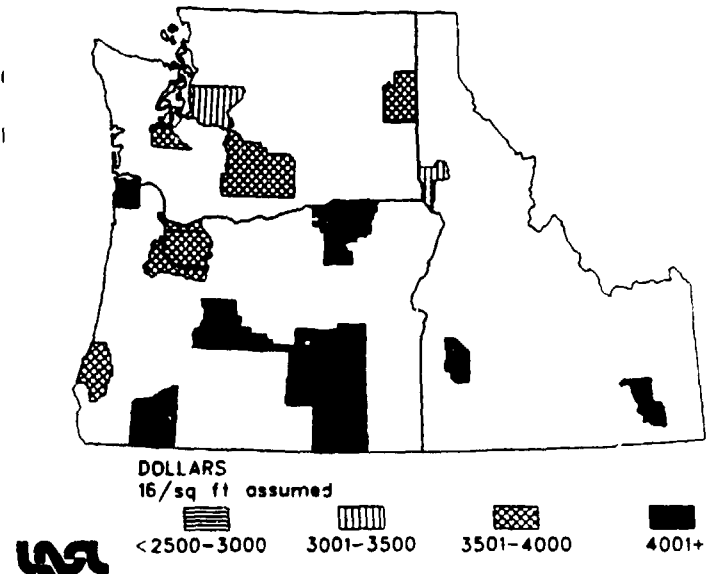SUMMARY OF ASSUMPTIONS USED IN ECONOMIC PERFORMANCE ANALYSIS

Regional Sites	15 SOLMET cities
Solar Systems Configuration	Trombe wall is 18 inches thick [1], Direct gain is for the surface area to mass ratio as Trombe wall i.e., 1.5 ft² of storage mass for every ft² of glass [2].
Energy Futures	Constant escalation rates for all locales in real terms) natural gas = 4%, electricity = 2%.
Energy Conversion Efficiency	Adjustment to account for losses; natural gas = 75%, electric resistance = 100%
Economic Variable - Values	(adjusted for inflation where necessary)
	Time Period of Analysis — 1979
	Solar System Lifetime — 30 years
	Inflation Rate — 6%
	Interest Rate (Real) — 3.5%
	Mortgage Rate (Nominal) — 9.5%
	Discount Rate (Nominal) — 9.5%
	Income Tax Bracket (Deduction) — 30%
	Property Tax — Solar add-on costs excluded
	Operating & Maintenance — 1% of Solar add-on costs (annually
	Down Payment — 20% of Solar add-on costs
	Resale Value (Recovered at end of Solar lifetime). — 0

FOOTNOTES

[1] Roach, F.; Noll, S.; Ben-David, S.; "Passive and Active Residential Solar Heating: A Comparative Economic Analysis of Select Designs," forthcoming in Energy: The International Journal

[2] Roach, F.; Ben-David, S.; "A Regional Comparative Analysis of Residential Passive Solar Systems: Thermal Storage Walls and Direct Gain," a paper contained in the Proceedings of the ISES Conference, Atlanta, Georgia, (May 28-June 2, 1979).

[3] "Determination of Passive, System Cost and Cost Goals," unpublished designs and preliminary cost estimates supplied to the authors by Total Environmental Action (TEA), work performed under DOE contract (April-May 1979).

[4] Wray, W.; Balcomb, J.; "Trombe Wall vs Direct Gain: A Comparative Analysis of Passive Solar Heating Systems," a paper contained in the Proceedings of the Third National Passive Solar Conference, San Jose, California (January 11-13, 1979).

[5] Unpublished data supplied to the authors by the Solar Energy Group, Los Alamos Scientific Laboratory (April 1979).

[6] Perino, A.; "A Methodology for Determining the Economic Feasibility of Residual or Commercial Solar Energy Systems," Sandia Laboratory, SAND 78-0931, (January 1979).

[7] American Gas Association, American Gas Association Rates Service, Vol. 1 & 11, Arlington, Virginia, (1977).

[8] U. S. Department of Energy, Typical Electric Bills, January 1, 1978, Energy Information Administration, Assistant Administration for Energy Data, Washington, D. C., Government Printing Office, (January 1978).

[9] Unpublished draft, "Estimating Allowable Heat Loss Factors," University of New Mexico/ LASL, (1979).

TABLE 2

FUEL PRICES

City/State	Natural Gas				Electric Resistance			
	1979*		1990		1979*		1990	
	$/10⁶Btu	$/MCF	$/10⁶Btu	$/MCF	$/10⁶Btu	¢/kwh	$/10⁶Btu	¢/k
Boise, Idaho	1.95	1.41	5.71	2.68	9.38	3.14	22.13	5.
Lewiston, Idaho	1.95	1.41	5.71	2.68	5.58	1.87	13.16	3.
Pocatello, Idaho	1.95	1.41	5.71	2.68	9.38	3.14	22.13	5.
Astoria, Oregon	7.10	5.12	20.75	9.72	9.57	3.20	22.58	6.
Burns, Oregon	7.10	5.12	20.75	9.72	9.44	3.16	22.28	6.
Medford, Oregon	5.34	3.85	15.79	7.30	9.57	3.20	22.58	6.
North Bend, Oregon	7.10	5.12	20.75	9.72	9.57	3.20	22.58	6.
Pendelton, Oregon	5.79	4.18	16.92	7.93	9.57	3.20	22.58	6.
Portland, Oregon	7.10	5.12	20.75	9.72	9.50	3.18	22.43	6.
Redmond, Oregon	5.79	4.18	16.92	7.93	9.57	3.20	22.58	6.
Salem, Oregon	7.10	5.12	20.75	9.72	9.50	3.18	22.43	6.
Olympia, Washington	6.19	4.46	18.08	8.47	7.25	2.43	17.12	4.
Seattle-Tacoma, Wash.	6.19	4.46	18.08	8.47	5.10	1.71	12.04	3.
Spokane, Washington	4.76	3.43	13.92	6.52	5.73	1.92	13.33	3.
Yakima, Washington	5.67	4.09	16.58	7.77	7.00	2.34	16.52	4.

*1978 Base Prices, Escalated

Table 4 (Continued)

TABLE 3

UPPER LIMIT OF VARIABLE COST FOR ECONOMIC FEASIBILITY BY SOLAR FRACTION

City/State	Natural Gas			Electric Resistance		
	.15	.30	.45	.15	.30	.45
Boise, Idaho						
TWNI	$ 5.95	$ 5.41	$ 4.76	$21.61	$19.68	$17.30
DGNI	6.40	5.66	4.88	23.25	20.57	17.75
Lewiston, Idaho						
TWNI	4.96	4.38	3.88	10.71	9.47	8.39
DGNI	5.22	4.53	3.88	11.29	9.80	8.39
Pocatella, Idaho						
TWNI	6.31	5.86	5.32	22.93	21.31	19.33
DGNI	6.65	6.06	5.32	24.19	22.03	19.33
Astoria, Oregon						
TWNI	19.06	18.12	16.50	19.47	18.50	16.85
DGNI	23.94	21.37	19.17	20.98	19.60	17.68
Burns, Oregon						
TWNI	22.66	20.64	18.62	22.83	20.80	18.76
DGNI	23.94	21.37	19.17	24.13	21.54	19.32
Medford, Oregon						
TWNI	13.81	12.30	10.98	18.76	16.71	14.92
DGNI	14.75	13.05	11.26	20.05	17.74	15.30
North Bend, Oregon						
TWNI	21.41	20.81	19.62	21.87	21.25	20.04
DGNI	23.68	22.72	21.05	24.18	23.21	21.50
Pendleton, Oregon						
TWNI	14.62	12.88	11.36	18.31	16.13	14.22
DGNI	15.5.	13.32	11.36	19.40	16.68	14.22
Portland, Oregon						
TWNI	17.86	15.66	13.38	18.12	15.89	14.03
DGNI	19.08	16.40	14.20	19.36	16.63	14.41
Redmond, Oregon						
TWNI	19.51	17.71	16.05	24.42	22.18	20.10
DGNI	20.89	18.82	16.47	26.15	23.56	21.83
Salem, Oregon						
TWNI	18.33	16.11	14.38	18.60	16.34	14.59
DGNI	19.69	17.09	14.75	19.97	17.34	14.96
Olympia, Washington						
TWNI	16.12	14.53	12.81	14.33	12.91	11.38
DGNI	17.11	15.02	12.81	15.20	13.34	11.38
Seattle-Tacoma, Washington						
TWNI	16.38	14.54	12.70	10.23	9.08	7.93
DGNI	17.53	15.00	12.70	10.95	9.37	7.93
Spokane, Washington						
TWNI	13.59	11.95	10.43	12.40	10.91	9.52
DGNI	14.17	12.19	10.08	12.93	11.12	9.20
Yakima, Washington						
TWNI	16.31	14.23	12.40	15.25	13.31	11.59
DGNI	17.29	14.72	12.40	16.17	13.75	11.39

TABLE 4

COSTS AND BENEFITS FOR ALTERNATIVE SYSTEMS

Fuel - Natural Gas   Variable Cost = $16/ft² Collector Area

City/State	Optimal Fraction	Collector Area (ft²)	Total Cost($)	Net Present Value($)	Simple Payback (Years)
Boise, Idaho					
TWNI	*NF	NF	NF	NF	NF
DGNI	NF	NF	NF	NF	NF
Lewiston, Idaho					
TWNI	NF	NF	NF	NF	NF
DGNI	NF	NF	NF	NF	NF
Pocatello, Idaho					
TWNI	NF	NF	NF	NF	NF
DGNI	NF	NF	NF	NF	NF
Astoria, Oregon					
TWNI	.30	226	3623	669	13
DGNI	.30	213	3404	949	12
Burns, Oregon					
TWNI	.35	289	4630	1684	12
DGNI	.35	283	4525	1814	11
Medford, Oregon					
TWNI	NF	NF	NF	NF	NF
DGNI	NF	NF	NF	NF	NF

(Continued)

Table 4 (Continued)

	Optimal Fraction	Collector Area (ft²)	Total Cost($)	Net Present Value($)	Simple Payback (Years)
North Bend, Oregon					
TWNI	.50	319	5101	1439	12
DGNI	.45	262	4193	1855	11
Pendleton, Oregon					
TWNI	NF	NF	NF	NF	NF
DGNI	.10	68	1087	42	13
Portland, Oregon					
TWNI	.15	109	1742	282	13
DGNI	.15	101	1621	436	12
Redmond, Oregon					
TWNI	.25	178	2847	570	12
DGNI	.30	206	3298	805	12
Salem, Oregon					
TWNI	.15	107	1709	347	12
DGNI	.15	99	1581	509	12
Olympia, Washington					
TWNI	.10	76	1213	60	13
DGNI	.10	70	1127	168	12
Seattle-Tacoma, Washington					
TWNI	.10	70	1126	98	13
DGNI	.15	101	1624	217	13
Spokane, Washington					
TWNI	NF	NF	NF	NF	NF
DGNI	NF	NF	NF	NF	NF
Yakima, Washington					
TWNI	.10	70	1119	121	13
DGNI	.10	65	1038	223	12

* NF = Not Feasible.

TABLE 5

COSTS AND BENEFITS FOR ALTERNATIVE SYSTEMS

Fuel - Electric Resistance   Variable Cost = $16/ft² Collector Area

City/State	Optimal Fraction	Collector Area (ft²)	Total Cost($)	Net Present Value($)	Simple Payback (Years)
Boise, Idaho					
TWNI	.30	222	3554	1138	1
DGNI	.35	256	4089	1363	1
Lewiston, Idaho					
TWNI	*NF	NF	NF	NF	N
DGNI	NF	NF	NF	NF	N
Pocatello, Idaho					
TWNI	.35	280	4483	1803	1
DGNI	.40	323	5170	1946	1
Astoria, Oregon					
TWNI	.30	226	3523	790	1
DGNI	.35	255	4083	1071	1
Burns, Oregon					
TWNI	.35	289	4630	1742	1
DGNI	.35	283	4525	1877	1
Medford, Oregon					
TWNI	.15	108	1726	416	1
DGNI	.20	139	2223	636	1
North Bend, Oregon					
TWNI	.50	319	5101	1622	1
DGNI	.50	299	4739	2035	1
Pendleton, Oregon					
TWNI	.15	115	1843	371	1
DGNI	.20	151	2416	525	1
Portland, Oregon					
TWNI	.15	109	1742	322	1
DGNI	.20	142	2265	484	1
Redmond, Oregon					
TWNI	.50	405	6478	2113	1
DGNI	.40	295	4717	484	1
Salem, Oregon					
TWNI	.15	107	1709	387	1
DGNI	.20	140	2234	555	1
Olympia, Washington					
TWNI	NF	NF	NF	NF	N
DGNI	NF	NF	NF	NF	N
Seattle-Tacoma, Washington					
TWNI	NF	NF	NF	NF	N
DGNI	NF	NF	NF	NF	N
Spokane, Washington					
TWNI	NF	NF	NF	NF	N
DGNI	NF	NF	NF	NF	N
Yakima, Washington					
TWNI	.10	70	1119	12	1
DGNI	.10	65	1038	115	1